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SHRINKAGE AND SPECIFIC GRAVITY VARIATION IN ROBUSTA EUCALYPTUS WOOD GROWN IN HAWAII

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A sample of 1691 pieces of wood collected from 50 plantation-grown *Eucalyptus robusta* trees was analyzed for specific gravity and volumetric shrinkage. Both specific gravity and shrinkage values increased with the distance from the pith and with tree height. The results suggest the possibility of sorting robusta lumber into groupings having narrower ranges of specific gravity and shrinkage by selecting boards according to locations in the tree.

Oxford: 176.1 *Eucalyptus robusta* (969) [-812:812.31:812.214].
Retrieval Terms: Eucalyptus robusta; specific gravity; wood shrinkage; wood characteristics; wood properties; Hawaii.

Eucalyptus robusta Sm., an important timber tree of Hawaii, has wood that shrinks considerably during drying. Dimensional changes caused by gain or loss of moisture often cause problems with joints in products made of this wood. Wood density can vary widely in robusta.[1] Probably because of this variation, shrinkage can also vary widely.

In South Africa, plantation-grown *Eucalyptus saligna* wood varies widely in specific gravity. Furthermore, shrinkage in drying also varies greatly in relation to specific gravity.[2] These conditions have an important bearing on the techniques required to use saligna lumber in laminated beams and other structures in which shrinkage and swelling may be a problem. I thought it likely that robusta eucalyptus would behave similarly.

I had gathered a large sample of robusta wood for a study of the extent of brittleheart in the species. This sample provided the opportunity to examine variation in specific gravity and shrinkage intensively with the object of determining whether such information would be of value in sorting or selecting lumber to increase its uniformity. The results of this study suggest that such sorting or selection is feasible.

PROCEDURE

The sample consisted of 1691 pieces of wood collected from 50 robusta eucalyptus trees in 10 stands on the island of Hawaii. These pieces, the remains of broken sticks originally 28 cm long, used in a toughness test, were about 2 by 2 by 10 cm. The sticks had been taken from each 1-1/4 inches of radius on either side of the pith, from cross-sections taken from stump height and from the top of each 16-foot log in each tree (*fig. 1*).

The samples, when measured for specific gravity in an earlier study, had an average moisture content of 14.1 percent. They had been oven dried for this determination and had subsequently been stored in

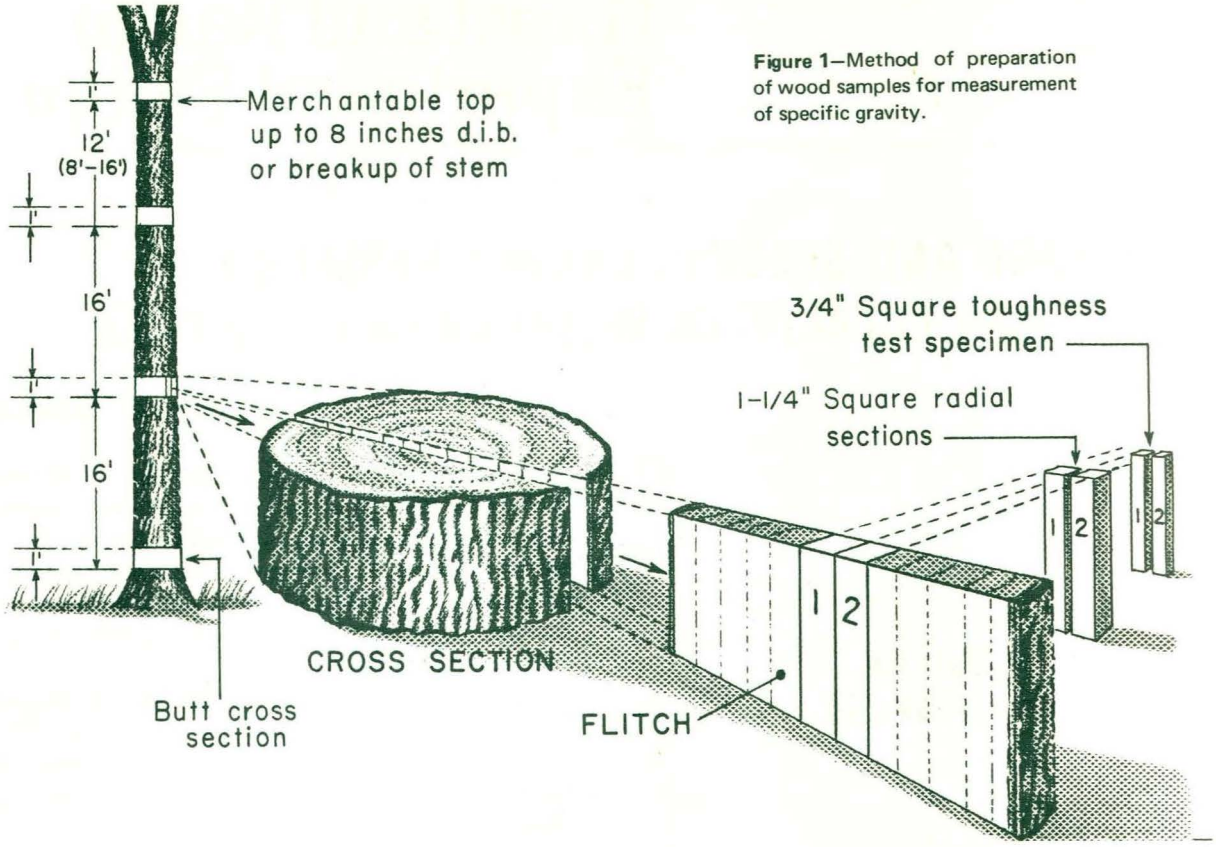

Figure 1—Method of preparation of wood samples for measurement of specific gravity.

ambient indoor conditions for about 3 years.

For this study, the weight, cross-sectional dimensions, and volume of each piece were measured in the air-dry state (8.6 percent), after swelling from the air-dry state in water at ambient room temperature to constant dimensions, and after oven drying. Volume measurements were made by water immersion. Swelling to constant size required that the pieces be soaked in water for 5 to 6 weeks. Weight was measured to 0.01 gram and dimensions to 0.001 inch.

A large but unmeasured portion of the shrinkage that occurred in the first drying of the samples was not recoverable in subsequent rewetting, so the specific gravity and shrinkage figures reported here are not the same as those that would occur in initial drying of wood after removal from the tree. The figures are useful, however, as measures of variation between and within trees. They are good indicators of the movement that might occur in wood in use.

The data calculated from these measurements were (a) basic specific gravity, based on swollen volume and oven-dry weight; (b) air-dry specific gravity, based on volume adjusted to 12 percent moisture content and oven-dry weight; (c) density at 12 percent volume and weight; (d) radial, tangential, and volumetric shrinkage in drying from the swollen condition to 12 percent moisture content and from the swollen condition to oven-dry condition. Comparisons were made within trees and between stands and with wood type (brittleheart, juvenile wood, normal heartwood, or sapwood).

RESULTS

Over-All Mean Values

Shrinkage from the swollen to oven-dry condition was lower than that found in the wood of eight robusta trees in the U. S. Forest Products Laboratory tests.[3] Radial shrinkage was only 77 percent and tangential shrinkage only 63 percent of the values found at the Laboratory. The difference is probably because of unrecovered "set" that occurred in original drying. Original "green" dimensions were probably not regained even though the soaked samples all reached a green moisture content of at least 40 percent.

Coefficients of variation were quite large for all values calculated (*table 1*). This may be partially the

Table 1—*Mean specific gravity and shrinkage of wood from a 50-tree sample of robusta eucalyptus*

Item	Soaked moisture content	Basic specific gravity[1]	Specific gravity at 12%[2]	Density at 12%[3]	Shrinkage					
					Swollen to air-dry weight			Swollen to oven-dry weight		
					Radial	Tangential	Volumetric	Radial	Tangential	Volumetric
	Percent			*Lb/ft*^{3}	*Percent*					
Value	46.7	0.58	0.62	42.8	2.8	4.1	6.7	4.7	6.7	11.7
Coefficient of variation	30.0	18.2	19.1	19.0	26.0	19.4	19.7	23.7	17.8	16.3

[1]Soaked volume, oven-dry weight.
[2]Air-dry volume adjusted to 12 percent moisture content, oven-dry weight.
[3]Volume and weight adjusted to 12 percent.

Table 2—*Basic specific gravity and volumetric shrinkage (green to oven-dry) of the sample, by stand and site characteristics, Hawaii*

Stand number	Age	Elevation	Rainfall	Mean d.b.h.	Mean merchantable height	Mean basic specific gravity[1]	Mean volumetric shrinkage[1]
	Years	*Feet*	*Inches*		*Feet*		*Percent*
1	44	1300	250	18.1	60	0.63 a	12.2 a
2	33	2200	115	19.6	56	.59 b	12.1 ab
3	33	2200	75	16.6	40	.56 c	11.5 cd
4	32	2600	85	16.4	40	.55 cd	11.3 d
5	34	2000	100	16.9	48	.54 d	11.6 bcd
6	31	1800	75	17.0	60	.59 b	11.9 abc
7	33	2200	85	20.0	60	.56 cd	11.6 cd
8	30	3600	75	16.6	24	.46 e	10.3 e
9	34	1600	225	16.2	44	.63 a	12.1 ab
10	34	1500	250	18.5	48	.60 b	11.9 abc
Means		–	–	17.6	48	.58	11.7

[1]Values followed by the same letters do not differ significantly at the 5 percent level of probability.

result of variation in set that occurred in original drying, but is also due to the large variation in these quantities within and between trees. Judging by shrinkage measurements made on other samples, it appears that much more of the radial shrinkage than the tangential shrinkage was recovered by soaking. This difference may account for the larger coefficients of variation in radial shrinkage.

Variation Between Stands

Basic specific gravity varied from 0.46 to 0.63 among the 10 stands (*table 2*). Stand averages for basic and air-dry specific gravity fell into five groups which differed significantly from each other. In only one instance, however, was the stand with different specific gravity also different enough in other charac-

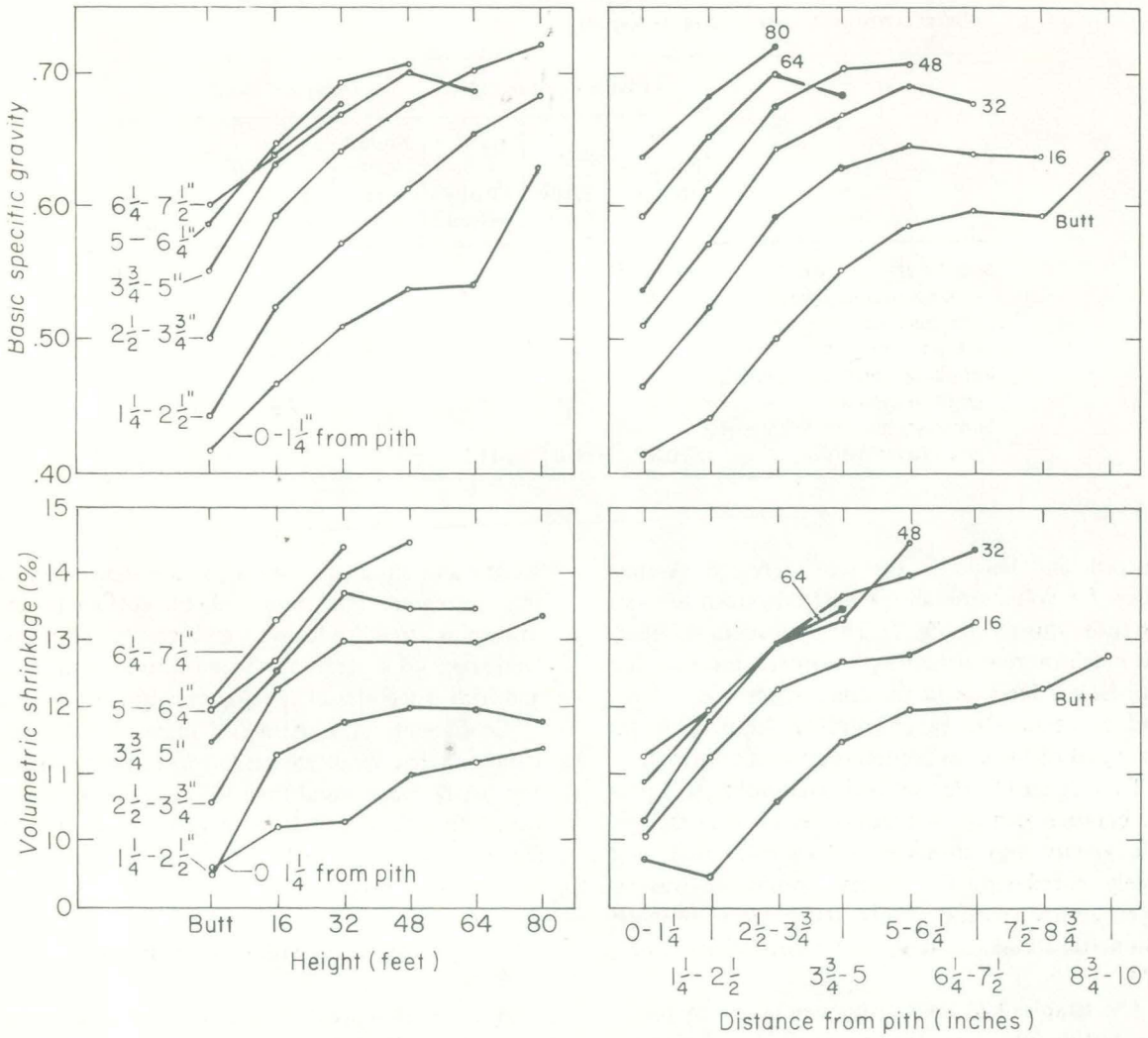

Figure 2—Relationship between basic specific gravity, volumetric shrinkage (green to oven-dry), height of sample in tree, and distance of sample from pith.

teristics so it might be preselected as having wood of different density. Wood shrinkage values were inconsistent from stand to stand. From a given stand, wood with high radial shrinkage might have low tangential shrinkage. The converse was also true.

The stand that had the lowest average basic specific gravity (0.46), also had the lowest radial, tangential, and volumetric shrinkage. The other nine stands did not have wood with a consistent relationship between specific gravity and shrinkage or between one shrinkage measurement and another.

The stand with low values grew at an elevation at least 1000 feet higher than the other stands. Perhaps the lower temperature of the higher elevation site may have resulted in the lighter weight and lower shrinkage of the wood. However, more observations are needed to ascertain if the effect of elevation is present in other stands.

Variation of Wood Within Trees

Basic specific gravity increased from pith to bark rapidly, but at a gradually diminishing rate as tree diameter increased (*fig. 2*). It also increased markedly as tree height increased. The wood tended to become more uniform in specific gravity in the outer part of the cross section regardless of height.

Shrinkage values also increased as distance from

Table 3—*Specific gravity and shrinkage (percent, green to oven-dry) within portions of a "typical" cross section of robusta eucalyptus*

Item	Juvenile wood (pink)			"Mature" wood		
	Pith area (brittle-heart)	Partly brash	Partly juvenile	Normal (dark) heart-wood	Partly sapwood	All sapwood
Specific gravity, soaked volume, oven-dry weight	0.47	0.52	0.58	0.65	0.67	0.68
Shrinkage, percent radial, green to oven-dry	4.0	4.3	4.8	5.3	5.4	6.1
Shrinkage, percent tangential, green to oven-dry	5.7	6.4	6.8	7.3	7.4	8.4
Shrinkage, percent volumetric, green to oven-dry	10.3	11.0	11.8	12.7	13.0	15.0

the pith and height in the tree increased. Average values for volumetric shrinkage from green to oven-dry show this trend (*fig. 2*). The increase in shrinkage was much more constant with diameter increase than with height increase in the tree. The wood did not tend to become more uniform in shrinkage in the outer part of the cross section regardless of height.

Though an obvious over-all relationship was present between density and shrinkage, none of the specific gravity and shrinkage values calculated were closely correlated. The closest correlation was between air-dry specific gravity and green to oven-dry volumetric shrinkage. It yielded a coefficient of only 0.73.

The samples had previously been sorted by toughness testing into those that were wholly or partly of brash wood and those that were of sound wood. Samples were also sorted by juvenile wood (light-colored), partly juvenile wood, all dark heartwood, partly sapwood, or wholly sapwood. Means of specific gravity and shrinkage were calculated for these categories.

My previous work[1] had shown a distinct placement of wood types within a cross section. The brash wood was centered about and near the pith. The slightly brash wood was just outside the brash wood. The nonbrash juvenile wood was outside the slightly brash wood. The dark heartwood was outside the juvenile wood, and the sapwood was outside the heartwood. The means for these categories, when compared, provide a good indication of the specific gravity and shrinkage variation that occurs within a typical robusta cross section (*table 3*).

These figures should be useful as guides to the weight and shrinkage of sorted robusta lumber. Both weight and shrinkage increased as distance from the pith increased. Therefore a simple sorting by color into pink, reddish-brown, and grayish-white (sapwood) would separate the wood into low, moderate, and high categories of specific gravity and shrinkage.

Coefficients of variation calculated for the means indicated that variation was larger for the brittleheart and partly brash wood than for the wood farther out from the pith. Coefficients of variation were smaller for the wood when sorted into these groups than for the over-all means.

Comparison with Previous Results

A previous report[1] based on these same samples gave an unadjusted air-dry volume, ovendry weight specific gravity of 0.603. I compared adjusted specific gravity values from the earlier study with those from the present study. It was not possible to match all samples because of missing data, but for those that could be matched, the specific gravity adjusted for volume at 12 percent moisture content became 0.611 for the old data and 0.626 for the new data. A simple t-test showed that the difference was not statistically significant.

DISCUSSION AND CONCLUSIONS

Though it was not possible to show a direct relationship between specific gravity and shrinkage, they both increased as distance from the pith and height in the tree increased. Because this variation in weight and shrinkage is large and can be troublesome, robusta wood should be grouped into batches of more uniform properties. This might be done in rare in-

stances by grouping wood from high elevation trees which may be of low specific gravity and shrinkage. A more common and useful technique would be to sort logs by location in the tree, because the lower logs have the lowest density, lowest shrinkage wood. Then by sorting the lumber from these logs into part or wholly sapwood, outer heartwood, and juvenile wood, it should be possible to obtain reasonably uniform batches. Furthermore, this practice would provide several strength grades because the wood increases in strength as specific gravity increases.

If robusta is to be used for laminated beams, sorting would be especially desirable in order to reduce the chance of placing pieces with very different shrinkage characteristics in the same beam. Such placement might cause glue joints to break down because of shrinkage or swelling stresses when the moisture content of the wood changed.

NOTES

[1] Skolmen, Roger G. 1972. *Specific gravity variation in robusta eucalyptus grown in Hawaii.* USDA Forest Serv. Res. Paper PSW-78, 7 p., illus. Pacific Southwest Forest and Range Exp. Stn., Berkeley, Calif.

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